

Next, as shown in FIG. 2C a layer of silicon germanium 222 is formed on the P-active region 10P. Prior to forming the layer of silicon germanium 222, a pre-clean process may be performed to remove materials such as native oxides from the surface of the P-active region 10P. The pre-clean process may be performed using, for example, a HF in either a wet or dry etching process. The layer of silicon germanium 222 may be formed by a variety of techniques, e.g., by performing an epitaxial growth process in a deposition chamber using current day epitaxial deposition tools and techniques, etc. In one illustrative embodiment, the layer of silicon germanium 222 may have an as-deposited thickness of approximately 20-30 nm, and it may have germanium concentration ranging from approximately 23-30% germanium as originally formed.

Next, as shown in FIG. 2D, the device 200 is exposed to an oxidizing ambient 224 comprised of, in one illustrative example, pure dry oxygen to form a layer of silicon dioxide 226 on the layer of silicon germanium 222. The duration of the exposure to the oxidizing ambient and conditions of the oxidation process may vary depending upon a variety of factors such as the final desired configuration of the device 200. In one illustrative example, the oxidation process may be performed in any acceptable process tool, e.g., a furnace, at a temperature ranging from 800-1200° C. for a duration of approximately 30-120 minutes. In one particularly illustrative example, the oxidation process may be performed at a temperature of approximately 1000° C. for a duration of approximately 60 minutes. In one illustrative example, the layer of silicon dioxide may have a thickness ranging from approximately 30-40 nm. The oxidation process effectively reduces the amount of silicon in the original layer of silicon germanium 222 because silicon is preferred over germanium in the oxidation process. The oxidation process and the formation of the layer of silicon dioxide 226 results in the formation of a layer of silicon germanium 222C having an increased concentration of germanium as compared to the germanium concentration in the layer of silicon germanium 222 as it was originally formed in the epitaxial deposition process. For example, whereas the original layer of silicon germanium 222 may have had a germanium concentration of approximately 23-30%, after the oxidation process, the resulting layer of silicon germanium 222C may have a concentration ranging from 40-90%. Theoretically, using the techniques disclosed herein, the germanium concentration in the resulting layer of silicon germanium 222C may be on the order of approximately 100%. It should also be noted that, as a result of the formation of the layer of silicon dioxide 226, some of the original thickness of the original layer of silicon germanium 222 will be reduced. In one illustrative example, where the original layer of silicon germanium 222 has a thickness of approximately 20-30 nm, the final layer of silicon germanium 222C may have a thickness ranging from approximately 5-10 nm, depending upon the parameters and duration of the oxidation process.

Additionally, the concentration of germanium in the resulting layer of silicon germanium 222C may not be uniform throughout its thickness. That is, the concentration of germanium in the resulting layer of silicon germanium 222C may be higher near the upper oxidized surface 222U than at the bottom surface 222B of the resulting layer of silicon germanium 222C. The exact distribution of germanium in the resulting layer of silicon germanium 222C may vary depending upon the particular details of the oxidation process. In one example, the increased concentration of germanium penetrates into the resulting layer of silicon germanium 222C for at least a distance of 20-60 nm from the oxidized surface 222U. However, it should be understood that when it is stated

that the layer of silicon germanium 222C has an increased concentration of germanium as compared to the germanium concentration in the original layer of silicon germanium 222 as it was originally formed in the epitaxial deposition process, that such increased concentration may be at any point throughout the thickness of the final layer of silicon germanium 222C.

Thereafter, as shown in FIG. 2E, the layer of silicon dioxide 226 may be removed at some later point in processing by performing an etching process. The masking layer 220 may also be removed at some point in processing after the layer of silicon germanium 222C is formed. At the point depicted in FIG. 2E, the device 200 may be subjected to additional processing to complete the formation of the desired semiconductor devices. For example, as shown in FIG. 2F, a novel PFET transistor 200P may be formed that is comprised of the final layer of silicon germanium 222C having the increased germanium concentration as described herein.

In another illustrative embodiment, as shown in FIG. 2G, an etching process 230 may be selectively performed on the P-active region 10P to form a recess 232 in the P-active region 10P prior to the formation of the original layer of silicon germanium 222. The type of etching process 230 performed, e.g., wet or dry, the etchant(s) used, and the parameters of the etching process 230 may vary depending upon a variety of factors such as the material of the P-active region 10P and the nature of the device under construction. The depth of the recess 232 may be selected such that, when the device is completed, the upper oxidized surface 222U is approximately level with the surface 10U of the N-active region 10N. Thereafter, as shown in FIG. 2H, the layer of silicon germanium 222C with increased germanium concentration is formed in and above the recess 232 using the techniques previously described. That is, an oxidation process is performed to form the silicon dioxide layer 226 to thereby result in the layer of silicon germanium 222C having a higher concentration of germanium than the originally formed layer of silicon germanium (which is not shown in FIG. 2H). FIG. 2I depicts another embodiment of a novel PFET transistor 200P comprised of the final layer of silicon germanium 222C having the increased germanium concentration as described herein, wherein the P-active region 10P was recessed prior to the formation of the original layer of silicon germanium as described above.

The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. For example, the process steps set forth above may be performed in a different order. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

What is claimed:

1. A method, comprising:

forming layer of silicon germanium on a P-active region of a semiconducting substrate, said layer of silicon germanium having a first concentration of germanium;  
performing an oxidation process on an exposed upper surface of said layer of silicon germanium to increase a concentration of germanium in at least a portion of said layer of silicon germanium to a second concentration that is greater than said first concentration; and